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Title:	THIRD QUARTERLY REPORT - THREE PHASE CENTRIFUGE CONTROL SYSTEM
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Third Quarterly Report – Three-Phase Centrifuge Control System

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Review

Los Alamos National Laboratory has been asked to build an intelligent setup and control system for the three-phase centrifuge designed and is operated by Centech Inc. The Los Alamos work is an effort to make it possible for non-experts to operate the Centech machine. The three-phase centrifuge is a portable device that is used for cleaning up oil field and refinery wastes. It is also being considered for in-line processing for both refinery and oil field operations. Unfortunately, at the present time only Neal Miller, the inventor of the centrifuge system, can operate the system optimally. This limitation reduces the potential for this system to make an impact on US oil field and refinery environmental problems. The centrifuge, in addition to supplying clean up services, recovers pipeline grade oil from the wastes. Therefore it has the potential to make some impact on US oil supply problems. The Los Alamos control system will make it possible to deploy centrifuges to many locations at one time and therefore more fully utilize their capabilities.

Beginning this year, the state of Wyoming has allowed operators to dispose of their waste oil on the roads. Apparently some operators believe that this alternative is a less expensive waste disposal alternative than using the centrifuge. Even though this is not always true, the situation has kept Centech from operating the centrifuge in the normal manner and has limited the early Los Alamos efforts to computer work rather than fieldwork.

With the recent increase in the price of oil, operators are beginning to take another look at Centech, because of their ability recover saleable oil from the waste. Centech recently obtained an oil field job, with Wold Oil, in a field about 50 miles southwest of Casper, Wyoming. They were asked to clean up about 3,000 bbls. of waste oil and produce a product that was pipeline grade. The Los Alamos team was able to visit the site and carry out some of their assigned tasks that required the centrifuge to be in operation. The oil at this site is relatively clean. It is a paraffin base and contains about 10-15 % BS&W and a thin polymer phase. In April, Centech is scheduled to go to another site in Vernal, Utah and clean up a waste sludge that is asphaltene based and has a very high BS&W content. It will be very useful to compare set up and operating procedures required for the two different jobs.

Because of the earlier centrifuge inactivity we had been forced to address some of our milestones out of sequence. Now that Centech is in the field we are getting back into

sequence and by the end of next quarter, with a little luck, should actually be ahead of schedule.

Major Tasks Accomplished —second quarter-- FY00.

Background

This is actually the third quarter of the project.

In March, Centech obtained a contract for an oil field cleanup near Casper, Wyoming. The job was to recover pipeline grade oil from waste oil containing 10-15% BS&W in addition to some polymer. This job will take a little over three weeks if everything goes as planned. The Wyoming requirement for pipeline oil is less than 0.3% BS&W. Centech was easily able to produce "trace oil" or 0.1% BS&W or less, with their centrifuge. We were able to verify this both with bench centrifuge "grind outs" and our BS&W control sensor, residing on the centrifuge product tank.

In April, Centech is scheduled to go to Vernal, Utah to work on what appears to be tar sands mixed with an asphaltene type oil. This work will be a quite different than some of the projects that we have worked on with Centech in the past. It is extremely different than the current Centech project. The project will probably involve the addition of some chemicals to the feed stream. This addition is not needed for the current job. This work will provide a significant and welcome challenge. It will provide the experience that we need in order to apply our set up and control system to widely varying feed sources. It will be an excellent experience to go through the set up procedure and the chemical addition logic for Vernal scenario.

On the week of March 13-17, the Los Alamos team was on site with Centech near Casper, Wyoming. Our basic task was to get the old control system back on line after a long period of inactivity, and add some of our enhancements. A list of tasks attempted and completed during this trip is presented below.

- We rerouted our product BS&W sensor in order to get better and more timely readings. The old method was to place the sensor on the outlet from the product oil holding tank. Since this tank was normally pumped down only when it was full, the successive BS&W readings were often on the same product oil sample. This presented the control system with a random time delay. The new system added a pump around, where the oil from the product tank is continually pumped through the BS&W sensor. This technique provides a "real time" product BS&W reading for the control system. This is important since the product BS&W is the most important feedback variable.
- This system worked very well, with one exception. Periodically air is introduced into the sensor. We have not determined whether this is from pumping from a nearly empty product tank, or whether there is an air leak in our pump around system. We are trying to find the air leak and fix it and/or provide a numerical filter that will remove the noise signal frequency from the sensor reading.
- We ran some tests to determine the BS&W reading, or error, as a function of temperature. We have analyzed that data and will apply the correction algorithm that we developed on our next visit. Our system is currently set up so that we need to

calibrate the BS&W meter only once per job. The temperature dependent correlation will improve our precision and the confidence in our readings.

- We experienced some problems with our liquid-level control sensors that reside on the product oil and water tanks. The problem disappeared when we disconnected the tanks from our main control panel. This suggests some sort of short circuit that we were unable to isolate during our visit. Even though the liquid-level sensing of the product tanks is not part of our main control system, having automatic pump-off and level control will make the centrifuge easier to handle and more user friendly for future workers who are less experienced with the process.
- We also experienced some problems with our flow meter. The flow meter works on an ultrasonic principle, sending a sound wave into a fluid and receiving a signal back. In order to send the signal back, the fluid must contain particles. The flow meter does not work with pure clean water. The contaminated waste oil feed, found at this site, was relatively clean compared to some systems that we have worked with in the past. We actually tried adding product water to the feed to increase its BS&W content. After continued talks with the flow meter factory representatives, we concluded that there was a real problem with the meter and we returned it to the factory. The current feedback version of the control system will run without the flow meter in the system. The fuzzy controller does manipulate both the feed rate and the feed temperature, based upon the product BS&W, but it just adjusts them up or down from their current value. We don't necessarily need to know what that value is. So we were able to field demonstrate our control system, but only the old version. The new, improved, version will require knowledge of the flow rates. Our feed-forward controller, that is specifically designed to eliminate feed disturbance rejection, needs information about the amount of water, solids, and oil in the feed stream. This information will be supplied by our soft-sensor that requires knowledge of the feed rate.
- Centech has upgraded their control computer since the last time we ran the centrifuge control system. We have installed the control software and hardware on the new computer, but we are now encountering some difficulty. In the manual mode, the software does not allow some variables to be set. This was definitely not the case with the old computer. The exact same software run on the Los Alamos computers does allow these variables to be set. There is probably some machine-software incompatibility that we have to identify and remedy.

We had hoped that all of our equipment problems were behind us, but this is probably very unrealistic. We are, after all, working in the field with real equipment under real operating conditions. This is not a laboratory or controlled environment. When equipment has not been used for about a year, and has been transported over rough terrain, and operated in a severe out door environment, we have to expect some equipment problems. What we learn about equipment durability will probably help in the long run. Although the notes above make it sound like we had a difficult time during the last Centech visit, we actually accomplished quite a bit. We should have our equipment problems ironed out in short order.

Milestone Progress:

From FY99

1. Begin compiling database necessary to develop the expert setup consultant.
   - This work is ongoing. There is a lot of information to deal with, but work is progressing nicely. Some, but not all, of the information is in rule form. We expect to add significantly to this database when Centech begins work in Vernal, Utah, working with asphaltenes.

2. Optimize existing membership functions, and implement control of throughput, temperature, centrifuge speed, oil quality, and adaptive control of sample rate.
   - We attempted to optimize the existing membership functions, but our results were not good because of the defective flow meter. We will have to redo this task when the flow meter is repaired.
   - We have all of the other items under control and working, except the centrifuge speed. In the case of the centrifuge speed, Centech must purchase a variable drive unit, before we can work on controlling product quality with bowl speed. We are adding the control of the conveyor. This control variable is built into the fuzzy rule bases that we are using for feed-forward control.
   - The adaptive control algorithm is ready but cannot be implemented until the flow meter is fixed. The adaptive sample control is based on residence time of the material in the bowl. The residence time is controlled by the flow rate. The adaptive control algorithm requires knowledge of the flow rate.

From FY00

1. Determine and locate sensors suitable for the measurement of water quality, solids quality, centrifuge speed, solids loading within the centrifuge, and solids discharge rate.
   - We have identified some water quality measurement devices, but we must test them. We have had vendors in the past indicate that their device would work for our situation and they didn't. We had one experience like this with was a water quality device.
   - We are not having much luck with on-line real-time solids quality measuring devices to this point. I hope there is something available, at a reasonable price that actually exists.
   - The centrifuge speed sensor is just a tachometer. If and when we get a variable speed bowl, this will be easy to implement.
   - We believe that we have a device located that will measure the torque applied by the conveyor. This sensor will provide a measurement of the solids loading in the centrifuge. This "torque meter" is available through the manufacturer of the Centech machine. We intend to use it for determining "overload" and with our soft-sensor.
   - We intend to measure the solids discharge rate with a scale-type device. At this point, we are not certain how much value will be added by using this device.
2. Investigate the use of feed-forward control techniques for disturbance rejection and for optimization of delivery of separation enhancing chemicals.

- We have done a great deal of work on the feed-forward control system. We have included figure 1 from our last quarterly report, in this report as well, so that we can describe our progress a little better. We have acquired a BS&W sensor for the feed. It has a greater range than the BS&W meter used to measure our product oil. It is also less sensitive. This is adequate for our feed-forward work. The feed-forward rules are based on feed temperature change, percent water in the feed change, and percent solid in the feed change, as shown in figure 1. The problem is determining the percent change in the solids and the water from the feed BS&W measurement. This is the reason for using a soft-sensor. The soft sensor will be discussed in another section. This fuzzy computer code has been written, complete with membership functions, and is ready to be implemented. It does need the soft sensor in order to work.
- We have obtained information on the delivery of chemicals to the system when they are needed. This is usually determined, to some degree, after the initial measurement of the qualities of the feed stock. The actual amount is then fine-tuned based upon feed back results. We are hoping to capture some of this technique in the expert set up system and provide the fine-tuning in the control system. It is not clear yet how much of the fine-tuning can be provided by feed-forward techniques as opposed to feed back. We will probably get some "hands on" experience with chemicals at the Vernal operation.

3. Implement instrumentation necessary for measurement of water quality, solids quality, centrifuge speed, solids loading within the centrifuge, and solids discharge rate.
   - We are still re-implementing the old instrumentation and the feed BS&W sensor. One reason for not being further along with this task is the need to test sensors before purchase and we really need to test them under operating conditions.
4. Field demonstration of the improved control system.
   - We only have our small improvements working so far. So our "field demonstration" last week just proved that the old system will work with small improvements. We are pretty certain that we will have a good field demonstration of the updated system by the end of FY00, based upon our current progress.

FY01

1. Incorporate into the control system the optimized delivery of separation-enhancing chemicals based on feedback from the quality of the product oil.
   - We have done some planning for this step and feel that the Vernal, Utah test will be our best opportunity to try this concept.

Comments on the Soft-Sensor Work

We have developed a soft-sensor to determine the percent change in the feed water and feed solid based on flow measurements, feed BS&W measurements, and heater measurements. To this point, we have used 45 rules. These rules and their corresponding membership functions have been coded and are ready to implement. We have one problem. Even though the rules are well defined, the membership functions are not. The

idea behind the soft-sensor is this. If the feed BS&W changes, how much is due to a change in water and how much is due to a change in solids. Our expert, Neal Miller, President of Centech Inc., has provided the 45 rules. These rules are based on his experience with feed composition changes during his operations. He has a good understanding of what happens to the flow rates and heater requirements when feed composition changes occur. For example rule 1(in English) is:
If there is a large negative change in the feed flow rate, and a negative change in the feed BS&W, and negative change in the heater requirements the water percent change is negative and the solid change is negative.
This is a good rule, but we need to define the range of the membership functions:

- Large negative feed-flow rate.
- Negative feed BS&W.
- Negative heater requirements.
- Negative feed-water percent change.
- Negative feed-solid percent change.

We need to obtain numerical values from these membership functions so that they can be converted into the power requirements needed to change the conveyor speed, the pump speed, and the heater set point. On our previous visits to Casper, during the period that the centrifuge was not running, we spent hours working on these rules and ranges with Mr. Miller. We wrote some computer programs that he could use and respond to as if he were operating the centrifuge. We collected and analyzed a good deal of data from this work. This is helping us with the numerical description of the membership functions described above. One problem is that Mr. Miller is most comfortable with the two output membership functions. In other words, his experience is better suited to answer the question:
1- If the water change is negative 10% and the solid change is negative 10% then what is the change in feed flow, the feed BS&W, and the heater requirements.
Than the question:
2- If the feed flow is negative 10% and the feed BS&W is negative 10%, and the heater requirements are a negative 10% what will changes in feed water percent and feed solid percent be?
The rules, like rule 1 above, are in the form of question two. This is the form that we need for our soft sensor. Mr. Miller was very consistent in answers to question of type one. Nearly all of the computer questions answered mapped correctly back a proper rule antecedent. This helps in mapping out the membership functions but there is still a problem. Questions of type two have unique answers and questions of type one do not. For example there are seven different combinations of feed flow change, and feed BS&W change, and heater requirement changes that lead to negative changes in the feed water and feed solids. Again, all 45 rules stated in the form of rule two are unique. But we are not able to determine range and shapes of the membership functions for the 45 rules as well as we would like to, from answers to questions of type one.
We believe, based on our discussions with Mr. Miller, that adding the variable torque placed upon the conveyor to our rule base (high torque is an indication of solids loading), will help clarify our problem. The torque variable is represented by the question mark shown in figure 1. A problem with adding this variable is that our soft sensor will

probably require 240 rules instead of 45 rules. This represents a major task because it is hard to get 240 rules about one subject from any expert. Two approaches that we have started working on to help us build the larger system are:

1. A neural network based upon the data that we have collected from Mr. Miller. This approach shows promise but we will need a lot more data.
2. A new method for generating fuzzy rules from data. [1].

We will possibly end up using a combination of these two methods.
This has turned into a rather difficult problem but there are several ways to solve it, and we believe that we are close to solving it.

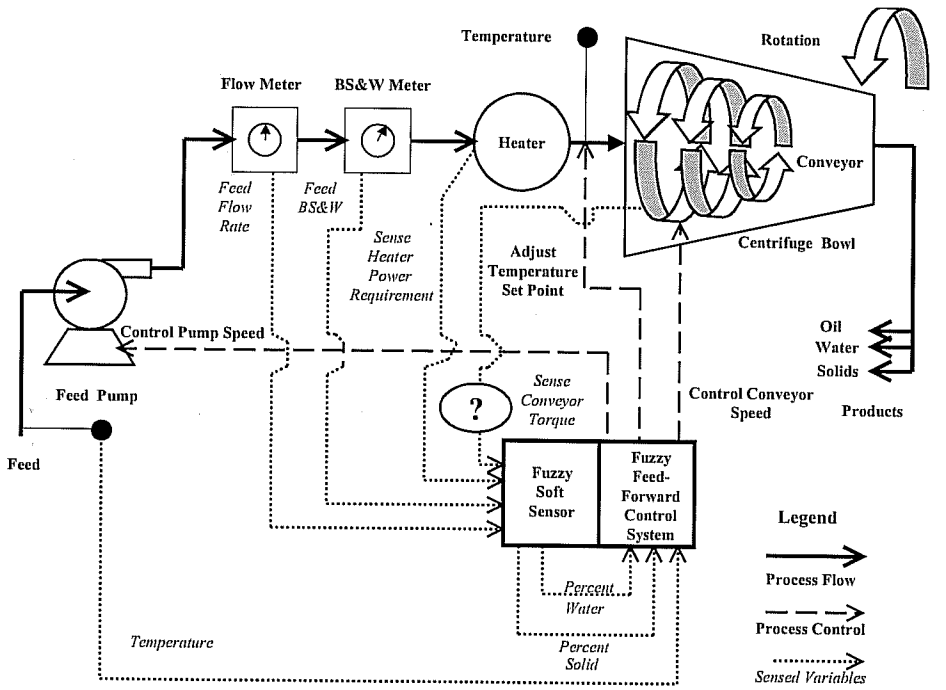

Figure 1. The schematic diagram for the fuzzy feed-forward control system and the fuzzy soft sensor.

Reference:

1. Wang, Li-Xin, and Jerry M. Mendel, "Generating Fuzzy Rules from Numerical Data, with Applications" USC-SIPI Report #169, Signal and Image Processing Institute,

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